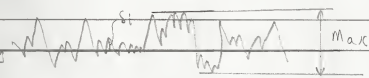
4- Out of straightness

* - Horizontal surface: It is the tangent to earth or any bubble
  - Smooth surface: It is the surface with no roughness
  - Flat surface: It is the surface which is perfect surface

* Form errors:
  - Out of straightess
  - Out of flatness
  - Out of squarness
  - Out of roundness
  - Out of parallelism
  - Others

* - Straightness measurements include surface inclination, zero error and B.C.s errors
  - Errors are removed by FWD & BWD readings

* Out of Straightness: It is the departure of surface from the true straight line
  - Max. out of straightness: It is the min. distance between 2 lines containing the irregularities of edge tested

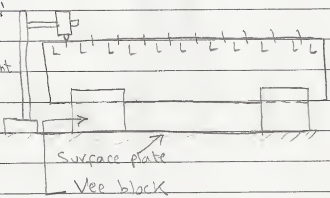


Eg) Out of straightness of point (1)

* Experimental procedure:
- The entire length of the edge is divided into equal intervals
- The variations in heights of the end points at each interval are determined experimentally
- The experimental readings are related to a certain datum
- The complete profile of the edge is obtained by linear interpolation
- The heights of the discrete points may be determined by using dial indicator, sensitive level or auto collinator

* Measuring straightness:
1- Using dial indicator:

Point	Reading (Max. reading)	Relative height
1	x	x
2	y	x+y
3	z	x+y+z
⋮	⋮	⋮



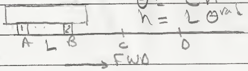
2- Using sensitive levels:
- Block sensitive level:

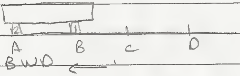
Level constant, No. of devisions moved by bubble

$\theta = C n$

$h = L \theta^{rad}$

Line	FWD (A - B)	BWD (B - C)	Average (By sign)
B_A	x	y	$\frac{x \pm y}{2}$
C_B	⋮	⋮	⋮
D_C	⋮	⋮	⋮



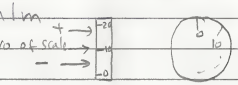


Point	Relative heigh
A	0
B	B_A
C	B_A + C_B
⋮	⋮

- Using optical clinometer;
- As sensitive level bot reading is to 0'

$$h = L \tan\left(\frac{\theta}{60}\right)$$

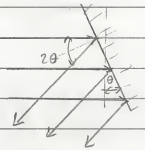
- Using micrometer clinometer
- S.V. = 0.01 mm/m



h = Reading − 10

$$\theta = \frac{h\ (mm)}{1000\ (mm)}\ [rad]$$

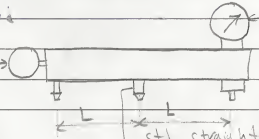
3 Using auto-collimator;

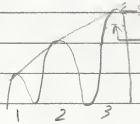


Calibrated scale

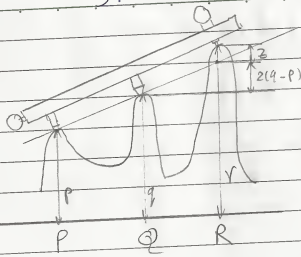
4 Using bar comparator (Rotchda' arm)

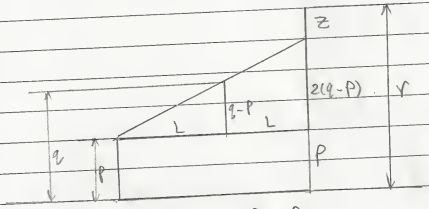
- No reference plate is needed





1-2-3 ⇒ +3 wrt. (1-2) line





$r = z + 2(q-p) + p$

$r = z + 2q - p$

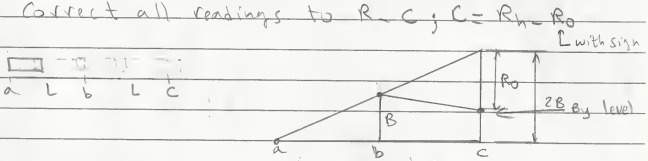
Point	Length(x)	Height(y)	
1	0	0	← It acts as inclination of plane
2	L	0	
3	2L	1-2-3+0+0	
4	3L	Lofo	
5	4L		
6	5L		

* Calibration of Rotchdale arm (Arm comparator):

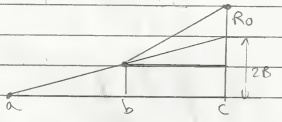
1- Take a reference reading on straight edge (R_0) to correct all reading to ($R - R_0$)

2- Using sensitive level

- Take a reading on line abc using Rotchdale arm (R_b)
- Determine the level of point (b) & c relative to (a) using sensitive level
- Determine the level of (c) relative to line $\overline{ab}$ mathematically (R_c)
- Correct all readings to $R - C$; $C = R_b - R_0$ (with sign)



$R_0 = C - 2B$

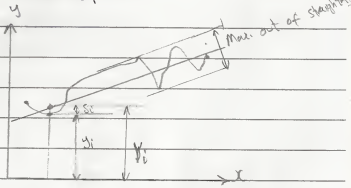


* The out of straightness calculations:

Real ← Mathematical

$\delta_i = y_i - Y_i$

Max $\delta_i = |\delta_{i\,max}| + |\delta_{i\,min}|$

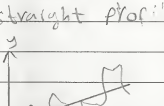


1- Graphical method:

A- Plot experimental readings

B- Plot a line representing the straight profile such that area under line = area above line

$Y = mx + C ; m = \frac{\Delta y}{\Delta x}$



2- Semi-analytical method:

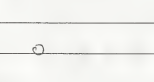
A- Join the 2 ends of points

B- Make the following table

x	y	$\delta_i = y_i - Y_i$
x_m	y_m	0

End point

$Y_i = \frac{y_{m-0}}{x_{m-0}} x_i$



3- Analytical method: least square method:

x_i	y_i	x_i^2	$x_i y_i$	Y_i	δ_i
Σ					

$Y_i = m x_i + C$

$m = \frac{n \Sigma x_i y_i - \Sigma x_i \Sigma y_i}{n \Sigma x_i^2 - (\Sigma x_i)^2}$

$C = \frac{\Sigma x_i^2 \Sigma y_i - \Sigma x_i \Sigma x_i y_i}{n \Sigma x_i^2 - (\Sigma x_i)^2}$